THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
JARVIS RIVER CULVERT REPLACEMENT
HIGHWAY 61
TOWNSHIP OF BLAKE, THUNDER BAY DISTRICT
G.W.P. 6304-14-00; SITE NO. 48W-183/C

GEOCRES No. 52A-223

Report

to

Hatch

Date: October 25, 2016
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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted for the proposed replacement of the Jarvis River Culvert on Highway 61, located in the Township of Blake, Thunder Bay District, Ontario.

The purpose of the investigation was to explore the subsurface conditions at the site, and based on the data obtained, to provide a borehole location plan, record of borehole sheets, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber carried out the investigation as a sub-consultant to Hatch, under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0017.

A preliminary foundation investigation carried out at this site for the replacement culvert was documented in the report titled "Foundation Investigation and Preliminary Design Report, Jarvis River Tributary Culvert Replacement, Highway 61, Township of Blake, Thunder Bay District", prepared by DST Consulting Engineers Inc. (DST), dated November 17, 2015; Geocres No. 52A-192. Reference should be made to the DST report for a written description of the subsurface conditions, borehole location plan, stratigraphic profile, records of borehole sheets and laboratory test results. It should be noted that DST is solely responsible for the subsurface information provided in the Foundation Investigation Report. The borehole logs from DST report are included in Appendix E. The information presented in the DST report was incorporated in the current report, as appropriate.

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2. SITE DESCRIPTION

The culvert site is located on Highway 61 approximately 0.4 m south of Cloud Lake Road in the Township of Blake, Thunder Bay District, Ontario. The Jarvis River flows from west to east at the culvert location.

According to MTO Plan E-441-61-3 for the Highway 61 crossing of Jarvis River (Site No. 48W-183/C), the culvert is a cast-in-place concrete box structure with a width of 6.7 m and a height of 2.7 m. The total length of the culvert is 42.6 m with approximately 8.0 m of fill above the culvert. The 2014 structure inspection report indicates severe delamination and cracking in culvert soffit.

Residential and agricultural properties are present in the vicinity of the culvert site. Naturally low-lying, swampy areas are present near the inlet and outlet of the culvert, with vegetation consisting of tall grass, shrubs and occasional trees. Local topography is of low relief with no evident bedrock outcrops. Photographs of the culvert and surrounding area are presented in Appendix C.

The site lies within the physiographical region known as the Animikie Basin of the Southern Province, which is characterized by sedimentary rock of the Rove Formation. According to Ontario Geological Survey (OGS) data, the bedrock at this site generally consists of black shale, siltstone and greywacke. The bedrock is overlain by glaciolacustrine and quiet basin deposits of the Pleistocene age consisting of silts, clays and minor sands.

3. INVESTIGATION PROCEDURES

The current site investigation and field testing for this project were carried out between March 19 and March 20, 2016. A total of three boreholes, denoted as JV-01 to JV-03, were advanced to depths ranging from 9.8 m to 20.4 m below the existing grade. Borehole JV-01 was advanced from the road embankment and Boreholes JV-02 and JV-03 were advanced near the culvert inlet and outlet, respectively. A Dynamic Cone Penetration Test (DCPT) was carried out below the sampled portion of Borehole JV-01 to a practical refusal depth of 29.2 m below the existing grade. Details of the borehole depths and completion are summarized in Table 3.1 below.

The locations of the boreholes from the preliminary and current investigations are shown on the attached Borehole Locations and Soil Strata Drawings included in Appendix D.

Boreholes JV-01 and JV-03 were advanced using a CME 750 buggy ATV drill rig in combination with hollow stem augers to advance the boreholes to the target depths. Borehole JV-02 was advanced to the target depth using a track-mounted CME 45 drill rig in combination with hollow stem augers. Samples of the overburden soils were obtained from the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Field vane shear testing using an MTO "N" size vane was carried out in cohesive soils.

Table 3.1 – Borehole Completion Details

Borehole Number	Borehole Depth/ Base Elev. (m)	Piezometer Installations		Completion Details
		Screen Depth (m)	Screen Elevation (m)	
JV-01	20.4 / 231.1	None Installed		Bentonite holeplug and cuttings from 20.4 m to 0.1 m, then asphalt to surface
JV-02	9.8 / 234.3	5.8 – 9.1	238.3 – 235.0	Backfilled with filter sand from 9.1 to 5.8 m, bentonite holeplug from 5.8 to 1.2 m, then cuttings to ground surface.
JV-03	9.8 / 233.2	4.9 – 8.2	238.1 – 234.8	Backfilled with filter sand from 9.2 to 4.9 m, bentonite holeplug from 4.9 to 4.3 m, then cuttings and bentonite holeplug to ground surface.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil and rock samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions in the open boreholes were observed during the drilling operations. Standpipe piezometers consisting of 25 mm PVC pipe with slotted screens were installed in Boreholes JV-02 and JV-03. Following the final water level reading, the piezometers were decommissioned in general accordance with MOE Regulation 903.

4. LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets included in Appendix A. Selected samples were also subjected to gradation analysis and the results of this testing program are summarized on the Record of Borehole sheets in Appendix A and shown on the figures included in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix A for details of the encountered soil stratigraphy. A stratigraphic profile is presented on the “Borehole Locations and Soil Strata” drawing in Appendix D. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond borehole locations.

The borehole logs from the previous foundation investigation (Geocres 52A-192) are presented in Appendix E and are generally consistent with the results of the current investigation.

The subsurface stratigraphy encountered below the existing embankment fill at the site generally consists of a clayey silt deposit that grades to a silt, which is further underlain by sand to silty sand. At the culvert inlet and outlet, these layers are overlain by a surficial layer of topsoil and sand with trace organics. More detailed descriptions of the individual strata are presented below.

5.1 Asphalt

Borehole JV-01 was advanced from the top of the road embankment and encountered 150 mm of asphalt. The thickness of the asphalt may vary in other areas of the site.

5.2 Sand

A 0.6 m thick surficial layer of brown sand was encountered in Borehole JV-02. The sand contained trace gravel, trace silt and trace organic matter (rootlets).

One SPT ‘N’ value recorded in the sand was 4 blows per 0.3 m penetration indicating a loose relative density. One measured moisture content in the sand was 52%. The high moisture content is likely attributed to the presence of organic material in the sample.

5.3 Embankment Fill

5.3.1 Sand Fill

Sand embankment fill was encountered below the asphalt in Borehole JV-01. The sand fill consisted of sand with trace to some gravel and silt, trace clay and occasional cobbles. The thickness of the sand fill was 6.2 m, with the base encountered at a depth of 6.4 m (Elev. 245.1).

SPT 'N' values recorded in the sand fill ranged from 27 to 49 blows per 0.3 m penetration, typically ranging from 45 to 49 blows per 0.3 m penetration indicating a dense relative density. The higher 'N' values are probably indicative of the presence of cobbles. Moisture contents of the sand fill ranged from 5 to 14%.

The results of a grain size analyses conducted on a sand fill sample is provided on the Record of Borehole sheets in Appendix A, and is illustrated in Figure B1 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	9
Sand	67
Silt & Clay	24

5.3.2 Clayey Silt Fill

Clayey silt embankment fill was encountered underlying the sand fill in Borehole JV-01. The clayey silt fill comprised clayey silt with some sand, trace gravel and trace organics. The thickness of the clayey silt fill was 2.3 m with a base depth of 8.7 m (Elev. 242.8).

SPT 'N' values recorded in the clayey silt fill ranged from 9 to 10 blows per 0.3 m penetration, indicating a stiff consistency. Moisture contents of the clayey silt fill ranged from 12 to 24%.

The results of a grain size analyses conducted on a clayey silt fill sample is provided on the Record of Borehole sheets in Appendix A, and is illustrated in Figure B2 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	3
Sand	16
Silt	66
Clay	15

5.4 Clayey Silt

A deposit of brown to dark grey clayey silt was encountered below the fill in Borehole JV-01, underlying the surficial sand in Borehole JV-02 and from the ground surface in Borehole JV-03. The thickness of the deposit ranged from 4.1 m to 5.0 m with the base of the clayey silt encountered at depths of 4.1 to 13.3 m (Elev. to 238.9 to 238.2). This layer contained trace to some sand with occasional sandy zones, trace gravel and trace organics.

SPT ‘N’ values recorded in the clayey silt varied between 1 and 12 blows per 0.3 m of penetration, typically between 3 and 7 blows per 0.3 m of penetration. SPT ‘N’ values recorded as 1 blow per 0.3 m penetration were observed in Borehole JV-03 indicating a very soft consistency. The vane shear tests (VST) measured in-situ undrained shear strengths ranging from 48 to greater than 105 kPa. Based on the SPT and VST data, the consistency of the clayey silt was described as soft to stiff with occasional very soft and very stiff zones.

Moisture contents of the clayey silt ranged from 19 to 78%, with most values between 28 and 45%. Higher moisture contents are likely attributed to the presence of organic matter in the samples.

The results of grain size analyses conducted on samples of the clayey silt are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B3 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0 to 4
Sand	9 to 35
Silt	47 to 74
Clay	14 to 27

5.5 Silt

A deposit of dark grey silt with trace clay and sand was encountered below the clayey silt in all of the boreholes. Where fully penetrated in boreholes JV-01 and JV-03, the thickness of this deposit ranged from 2.9 m to 3.0 m with the base of the deposit extending to depths of 7.0 to 16.3 m (Elev. 236.0 to 235.2). Borehole JV-02 was terminated in the deposit at a depth of 9.8 m or Elev. 234.3.

SPT ‘N’ values recorded in the deposit ranged from 0 to 7 blows per 0.3 m penetration, indicating a very loose to loose relative density. Moisture contents of the deposit ranged from 13 to 34%.

The results of grain size analyses conducted on samples of the silt are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B4 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0
Sand	6 to 9
Silt	84 to 86
Clay	7 to 8

5.6 Sand to Silty Sand

A deposit of dark grey sand to silty sand with trace clay and gravel was encountered below the silt in Boreholes JV-01 and JV-03. Both boreholes were terminated in this deposit at depths of 20.4 and 9.8 m, respectively (Elev. 231.1 and 233.2).

SPT 'N' values recorded in the deposit ranged from 3 to 23 blows per 0.3 m penetration, indicating a very loose to compact relative density. Moisture contents of the deposit ranged from 18 to 25%.

The results of grain size analyses conducted on samples of the sand to silty sand are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure B5 of Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	2 to 3
Sand	74 to 84
Silt	11 to 22
Clay	2

5.7 Groundwater Conditions

The water levels in the boreholes were measured upon completion of drilling operations. Standpipe piezometers were installed in Boreholes JV-02 and JV-03 to monitor groundwater levels after drilling. The water levels measured in the open boreholes upon completion of drilling and in the piezometers are summarized in Table 5.1.

The water level in Jarvis River was shown on Drawing E-441-61-3 for the crossing at Jarvis River and Highway 61 (Site No. 48W-183/C) at Elev. 241.8 at the culvert inlet and Elev. 241.7 at the culvert outlet on May 15, 2014.

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Table 5.1 – Water Level Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
JV-01	Mar. 20, 2016	7.1	244.4	Open borehole
JV-02	Mar. 20, 2016 Mar. 21, 2016 Mar. 22, 2016	2.2 2.4 2.4	241.9 241.7 241.7	Open Borehole Standpipe Piezometer Standpipe Piezometer
JV-03	Mar. 19, 2016 Mar. 20, 2016 Mar. 21, 2016 Mar. 22, 2016	0.2 0.2 0.2 0.3	242.8 242.8 242.8 242.7	Open Borehole Standpipe Piezometer Standpipe Piezometer Standpipe Piezometer

The water level in the river and groundwater levels are expected to fluctuate seasonally and are subject to precipitation patterns, and may vary from the levels presented above.

6. MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber obtained the northing and easting coordinates and ground surface elevations from measurements taken in the field relative to the topographic plans provided by Hatch.

RPM Drilling Inc. of Thunder Bay, Ontario supplied and operated a track-mounted CME45 hi-torque drill rig and CME750 buggy ATV drill rig to carry out the drilling, sampling and in-situ testing operations for the boreholes at this site.

The drilling and sampling operations in the field were supervised on a full time basis by Ms. Eckie Siu of Thurber. Geotechnical laboratory testing was carried out by Thurber in its MTO-approved laboratory. Overall supervision of the field program was carried out by Mr. Stephane Loranger, CET.

Ms. Deanna Pizycki, EIT and Mr. Keli Shi, P.Eng., interpreted the data and prepared the report. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7. GENERAL

This report presents interpretation of the geotechnical data provided in the factual report, as well as discussions and geotechnical design recommendations for the replacement of the existing culvert carrying Jarvis River under Highway 61 in the Township of Blake, District of Thunder Bay, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The MTO Inspection Report, dated February 10, 2014, indicates an extensive deterioration of concrete and rebar with heavy spalling and cracking in the soffit of the culvert, as well as undermining and scouring at the culvert ends. The MTO Plan E-441-62-3, titled “Crossing at Jarvis River and Highway 61”, dated May 2014 and revised in November 2014, indicated that the existing culvert has a span of 6.7 m and a height of 2.7 m. The top of obvert was shown at Elev. 243.5 and Elev. 243.6 at the inlet and outlet, respectively, and the invert of the culvert was shown at approximately Elev. 240.9. The water level in Jarvis River at the culvert location was shown at 241.8 at the inlet and 241.7 at the outlet on May 15, 2014.

The finish road grade at the culvert location is shown at approximate Elev. 251.4, which suggests approximately 8 m of fill above the culvert. It was assumed that no grade raise will be required to accommodate the replacement culvert.

The General Arrangement drawings available at the time of report preparation indicate the invert of the replacement culvert at Elev. 241 approximately and wingwalls/ headwalls are not proposed at this culvert.

The discussions and recommendations presented in this report are based on the factual data obtained during the course of the current investigation. The existing subsurface information collected for the preliminary design of the culvert replacement (Geocres 52A-192, Appendix E) was reviewed and incorporated in this report, where appropriate.

8. CULVERT DESIGN

8.1 Summary of Subsurface Conditions

In general, the subsurface conditions beneath the embankment fill consisted of a layer of soft to very stiff clayey silt grading to very loose to loose silt underlain by loose sand. The sand becomes compact to dense with depth.

The water levels in the open boreholes were measured between 0.2 m and 7.1 m depth (Elev. 241.9 and Elev. 244.4). The water levels is the piezometers were measured at 2.4 m and 0.3 m depths or Elev. 241.7 and 242.7, respectively. The MTO Plan indicates water levels in Jarvis River at Elev. 241.8 at the culvert inlet and at Elev. 241.7 at the culvert outlet on May 15, 2014.

8.2 Culvert Alternatives

Several common culvert types and installation methods that may be considered for the culvert replacement at this site are listed below:

- Concrete box (closed) culvert in an open-cut excavation
- Concrete open footing culvert in an open-cut excavation
- Precast slab on sheet piles
- Concrete pipe or steel pipe

The existing culvert consists of a reinforced concrete box. The following must be considered while selecting the preferred replacement alternative:

- Concrete open footing culvert will require deep excavation to found footings on competent stratum and this will require effective dewatering. This option is not recommended from a geotechnical perspective;
- Precast slab on sheet piles is considered a feasible alternative for culvert replacement given the embankment height and significant roadway protection requirement. However additional investigation consisting of deeper boreholes will be required to confirm design parameters. Therefore, this alternative is not further developed;
- Precast concrete box or pipe culvert installed in an open excavation is considered feasible and will require less excavation than the open footing culvert although this option will also require dewatering. Open excavation and temporary roadway protection with strutting, tiebacks or a deadman system will be required for this alternative in addition to installation of a temporary diversion pipe.
- Concrete pipe or steel pipe installed using trenchless methods will cause minimal highway traffic disruptions. Based on the encountered subsurface conditions, this alternative is considered a preferred replacement option in conjunction with lining of the existing culvert. It is understood that trenchless method is also the preferred option by the MTO for installation of the relief pipe culvert adjacent to the existing culvert.

The following sections present foundation recommendations for culvert replacement options including concrete box (open cut) and concrete pipe or steel pipe (trenchless methods).

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix F.

8.3 Foundation Design for Culverts

It is anticipated that the invert level of the replacement culverts will be similar to the invert of the existing culvert. There is approximately 8.0 m of fill above the existing culvert. Foundation design aspects for the replacement culvert includes discussion and recommendations on geotechnical capacities, settlement of founding soils, lateral earth pressures, protection system design, groundwater control, staged construction, and re-construction of the roadway embankment.

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8.3.1 Concrete Box Culvert

Since the replacement culvert will be constructed on the same alignment with no grade raise, it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading. Construction of a box culvert will require open excavation of the existing embankment and temporary roadway protection if the highway traffic is to be maintained during construction.

In order to provide a uniform foundation subgrade, a minimum 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the box culverts as per OPSD 803.010. The bedding material should be placed on the prepared subgrade as soon as practicable following its inspection and approval. The surface prepared to support the box units should have a 75 mm minimum thickness top levelling course consisting of uncompacted Granular A. Construction specifications outlined in OPSS PROV 422 should be followed. Subgrade preparation and culvert construction must be carried out in the dry. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

The underside of the bedding layer can be placed on the native clayey silt deposit at the design culvert base. The clayey silt below that level was typically firm to stiff, except at the east end of the culvert (JV-03), where clayey silt was soft to firm. In the areas where soft subgrade or organic material is encountered, these soils should be sub-excavated within the footprint of the culvert and replaced with well compacted granular soils.

The following geotechnical resistances are recommended for design of a 6 m wide box culvert and founded at or below Elev. 241 on the properly prepared competent clayey silt subgrade:

- Factored Geotechnical Resistance at ULS of 250 kPa
- Geotechnical Resistance at SLS (≤ 25 mm settlement) of 150 kPa

The ULS resistance and settlement are dependent on the footing/culvert size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed, if the culvert width or founding/invert elevation differs significantly from that given above.

The geotechnical resistances are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces / sliding resistance between the concrete slabs and the underlying Granular A or B Type II should be calculated assuming an ultimate coefficient of friction of 0.5.

Culvert should be designed to resist external loadings including lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

8.3.2 Concrete Pipe Culvert

Replacement of the culvert with concrete pipes on the same alignment as the existing culvert can be considered for this site. Multiple pipes will likely be required to meet the hydraulic requirements. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading.

The concrete pipes should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.034. The bedding material should be placed on the prepared subgrade as soon as practical following its inspection and approval. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which should be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elev. 241, which corresponds to the firm to stiff clayey silt subgrade. As noted in Sec. 8.3.4, in the culvert footprint areas where the soft subgrade or organic material is encountered, these soils should be sub-excavated and replaced with well compacted granular fill within the footprint of the culvert. Subgrade preparation and culvert construction must be carried out in the dry.

8.3.3 Frost Cover

The design depth of frost penetration at this site is 2.2 m. The base of all footings, if employed, must be provided with a minimum of 2.2 m of earth cover as protection against frost action. The frost cover requirement does not apply to the base of a box culvert or CSP.

Frost treatment should be as per OPSD 803.010 for a box culvert, and as per OPSD 803.030 or 803.031 as applicable for a pipe culvert. A frost taper is not required where the excavation backfill consists of non-frost susceptible granular material similar to the existing sand embankment fill.

8.3.4 Subgrade Preparation

Performance of the replacement box or pipe culvert will depend on the subgrade preparation. After the excavation has reached the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, river bed deposits, soft or loose soils, organics and any deleterious materials within the culvert footprint should be removed. In the event that sub-excavation is required, the width of the sub-excavation should be defined by a line extending from 0.3 m beyond the outside edge of the proposed culvert, outward and downward at 1H:1V. The sub-excavated area should then be backfilled with well compacted granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements.

The work should be carried out in accordance with OPSS.PROV 902.

The culvert installation and subgrade preparation should be carried out in the dry, and the construction dewatering should be effective to maintain the groundwater below the final subgrade level. Reference should be made to specifications in OPSS PROV 517 and OPSS PROV 518.

Once the subgrade is prepared, the construction equipment should not travel on the subgrade.

9. TRENCHLESS METHODS

We understand that the preferred option at this site is to install a 49.2 m long by 2.1 m diameter relief pipe adjacent to the existing culvert and then line the existing culvert. The relief pipe will also serve as a diversion pipe during construction to enable liner installation in the dry.

The relief pipe will be installed using trenchless methods. Based on the borehole information, the installation will be partly in cohesive fill material and partly in native clayey silt. The groundwater table is expected to be above the pipe invert.

Trenchless installations should be carried out in accordance with the requirements of the Non-Standard Special Provision (NSSP) "Pipe Installation by Trenchless Methods". A copy of this NSSP is attached in Appendix G.

Trenchless methods that are typically considered to install concrete and steel pipes under highways include:

- Jack and Bore (Horizontal Auger Boring)
- Pipe Ramming

- Micro-Tunnelling (MTBM)
- Horizontal Directional Drilling (HDD)

For this installation, pipe-ramming and micro-tunnelling are considered to be technically suitable alternatives. Pipe-ramming may be the preferred option due to the relatively short length of the installation. Pipes with diameter up to 3.5 m have been installed with pipe-ramming although most installations are with diameters less than 2.1 m. The typical maximum pipe diameter for micro-tunnelling is 3.0 m.

Selection of an appropriate trenchless method is the responsibility of the Contractor and will depend on the relative costs and risks associated with each method. The experience of the Contractor is of primary importance for trenchless installation. Amongst the important issues discussed in the NSSP are maintenance of alignment, handling of oversized obstructions and disposal of cuttings.

It should be noted that all trenchless methods will require a new alignment, and the clearance required between the existing culvert and new pipes for safe installation is typically between 1 to 2 diameters of the pipe to be installed. The preliminary GA shows that a clearance of 2.4 m is proposed between the edge of the relief pipe and the outer wall of the existing box culvert.

Settlement monitoring of the roadway surface should be carried out during trenchless installation. The settlement monitoring program and condition survey should follow the requirements of the NSSP “Pipe Installation by Trenchless Methods”.

9.1 Entry and Exit Pits

The design of entry and exit pits for the trenchless installation is the responsibility of the Contractor. Depending on the selected installation method, temporary shoring systems may be required to support excavations at the entry and exit pits.

Sheet-piles or soldier pile and lagging walls are considered appropriate for protection systems at this site. The existing fill was noted to include occasional cobbles. Suggested wording for an NSSP on “Obstructions” is found in Appendix G.

Earth pressures may be calculated using the parameters provided in the following table for static conditions.

Earth Pressure Design Parameters – Static Conditions

Loading Condition	Existing Sand Fill $\phi = 32°$; $\gamma = 21.0$ kN/m^3		Clayey Silt Fill or Native Clayey Silt $\phi = 26°$; $\gamma = 19.0$ kN/m^3		Silt $\phi = 28°$; $\gamma = 20.0$ kN/m^3	
	Horizontal Surface	Sloping Surface (2H:1V)	Horizontal Surface	Sloping Surface (2H:1V)	Horizontal Surface	Sloping Surface (2H:1V)
Active (Unrestrained Wall)	0.31	0.48	0.39	0.63	0.36	-
At rest (Restrained Wall)	0.47	-	0.56	-	0.53	-
Passive (Movement Towards Soil Mass)	3.3	-	2.6	-	2.8	-

The temporary excavation support system should be designed and constructed in accordance with OPSS 539. The lateral movement of the temporary shoring system should meet Performance Level 2.

Dewatering should be employed as necessary to keep the entry and exit pits dry.

10. EXCAVATION AND GROUNDWATER CONTROL

Excavation and backfilling for culvert construction should be carried out in accordance with OPSS PROV 902.

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native clayey silt at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposit that is anticipated in the inlet/outlet areas is classified as Type 4 soils.

Excavations for culvert replacement will be carried out through the existing embankment fill and extended into the native clayey silt deposit. The work will need to be carried out within a temporary protection system.

Groundwater perched within the embankment fill and surface runoff will seep into the excavations during culvert replacement. The groundwater level is expected to be largely governed by the water level in the river, therefore, the excavation and culvert installations will have to be carried out within a water-tight enclosure/cofferdam. For this site, the use of interlocking steel sheetpiles may be utilized. Sump pumping will be required to maintain dry excavations. The dewatering during construction should be effective to maintain the water level below the final subgrade level. The design of the dewatering system is the responsibility of the contractor. The contractor should retain a dewatering specialist to design the appropriate cofferdam and dewatering system. Suggested wording for an NSSP in this regard is included in Appendix G.

Reference should be made to OPSS PROV 517 and OPSS PROV 518 for specifications for dewatering and control of water from dewatering.

11. TEMPORARY PROTECTION SYSTEM

Temporary roadway protection system should be implemented in accordance with OPSS PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection).

Interlocking sheetpiles is one of the options to provide temporary support to the soils during excavation.

The following parameters may apply for design of the temporary roadway protection system with horizontal backfill.

γ	=	21 kN/m^3	(bulk unit weight of sand fill)
γ	=	19 kN/m^3	(bulk unit weight of clayey silt fill)
γ_w	=	10 kN/m^3	(submerged unit weight)
K_a	=	0.31	(Active pressure coefficient for sand fill)
	=	0.39	(Active pressure coefficient for clayey silt fill and native clayey silt)
K_p	=	3.3	(Passive pressure coefficient for sand fill)
	=	2.6	(Passive pressure coefficient for clayey silt fill and native clayey silt)
h_w	=	Elev. 241.8	(approximate elevation for hydrostatic pressure built-up behind temporary shoring)

The design of temporary protection system is the responsibility of the Contractor. The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors should be considered when designing the shoring system. All shoring systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

Temporary groundwater and surface water control measures will be required during construction.

12. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 803.01 or 802.034, as appropriate. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of a culvert, and the top of backfill elevation should not differ more than 400 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS 501.

Earth pressures acting on the culvert walls may be assumed to impose a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2014, but are generally given by the expression:

$$p_h = K(\gamma h + q)$$

where
p_h = horizontal pressure on the wall at depth h (kPa)
K = earth pressure coefficient (see table below)
γ = bulk unit weight of retained soil (see table below)
h = depth below top of fill where pressure is computed (m)
q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert walls or any wingwalls are dependent on the material used as backfill. Recommended unfactored values are shown in the table below.

Table 12.1 - Earth Pressure Coefficients (K)

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35°$; $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I (modified) $\phi = 32°$; $\gamma = 21.2$ kN/m^3		Embankment Fill $\phi = 30°$; $\gamma = 20.0$ kN/m^3	
	Horizontal Surface	Sloping Surface (2H:1V)	Horizontal Surface	Sloping Surface (2H:1V)	Horizontal Surface	Sloping Surface (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0	-

Note: Submerged unit weight should be used below the groundwater level/high water level in the river.

The parameters in the table correspond to full mobilization of active and passive earth pressures, and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the

Commentary to the CHBDC 2014. Active pressures should be used for any wingwalls or unrestrained walls. For rigid structures such as concrete box culverts, at-rest horizontal earth pressures should be used for design.

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 1.7 m for Granular B Type I, or at a depth of 2.0 m for Granular A or Granular B Type II.

13. SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.0
- Acceleration Related Seismic Zone 0
- Zonal Acceleration Ratio 0.0

The site is underlain by a very soft to stiff clayey silt and very loose to compact silts and sands. In view of the value of Velocity Related Seismic Zone of zero, liquefaction is not considered to be a concern at this site.

14. EMBANKMENT RECONSTRUCTION

The existing highway embankment is approximately 8 m in height at the culvert location. It is anticipated that no grade raise is proposed at this site.

The MTO Inspection Report indicates some longitudinal pavement cracks on the road shoulders and one transverse pavement crack at the culvert location, and described the overall embankment condition as fair. At the time of the inspection and the current field investigation, the embankment slope faces were covered with a large size rock fill blanket at the culvert location. No signs of global stability were observed.

Embankment reconstruction after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206. The embankment material may consist of imported Granular A or B Type II material. The embankment should be reconstructed to the existing condition and surficial slope stability may be improved with the use of rock fill blanket.

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In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from within the embankment footprints, as well as in the areas around the culvert inlets and outlets. Inspection and approval of the foundation surfaces by qualified geotechnical personnel should be conducted.

15. SCOUR AND EROSION PROTECTION

Erosion protection should be provided at the culvert inlet and outlet. Design of the erosion protection measures should consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all surfaces with which river water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS PROV 804.

A concrete cut-off wall or clay seal should be used to minimize the potential for piping or erosion around the box culvert. The clay seal should extend to approximately 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS PROV 1205.

A geo-synthetic clay liner may be used in place of a compacted clay seal.

16. CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to:

- Impact of trenchless operation on the existing pavement surface due to loss of material or heave. The contractor's methodology selection must recognize and take into consideration these inherent risks. Contingency plan should be in place to manage any adverse impacts on the highway. The settlement of the pavement surface must be monitored during the trenchless operation.
- The water level in the river may fluctuate and be at higher elevation at the time of construction than indicated in the report. Implementation of an effective dewatering system is critical in order to prepare the subgrade and construct the culvert in the dry.
- Cobbles or other buried obstructions may be encountered during excavation in the existing embankment fill and may interfere with installation of the temporary roadway protection system. Rock fill was present on the embankment slopes, which will require removal before installation of the roadway protection system.

- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

17. CLOSURE

Engineering analysis and preparation of the report were carried out by Mr. Keli Shi, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT(1) 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

1) Laboratory Triaxial Testing
2) Field Insitu Vane Testing
3) Laboratory Vane Testing
4) SPT value
5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

SS Split Spoon Sample
WS Wash Sample
AS Auger (Grab) Sample
TW Thin Wall Shelby Tube Sample
TP Thin Wall Piston Sample
PH Sampler Advanced by Hydraulic Pressure
PM Sampler Advanced by Manual Pressure
WH Sampler Advanced by Self Static Weight
RC Rock Core
SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

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RECORD OF BOREHOLE No JV-1

METRIC

GWP# 6304-14-00	LOCATION Jarvis River Culvert N 5 337 662.6 E 344 844.8	ORIGINATED BY ES
HWY 61	BOREHOLE TYPE Hollow Stem Augers/DCPT	COMPILED BY MFA
DATUM Geodetic	DATE 2016.03.19 - 2016.03.20	CHECKED BY DJP

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
251.5	GROUND SURFACE					
0.0	**ASPHALT:** (150mm)					
0.2	**SAND**, trace to some gravel, trace to some silt, trace clay, occasional cobbles Compact to Dense Brown Moist (FILL)	1	GS			
		1	SS	49		
		2	SS	27		9 67 24 (SI+CL)
		3	SS	48		
		4	SS	45		
		5	SS	46		
245.1 / 6.4	Clayey **SILT**, trace to some sand, trace gravel, trace organics Stiff Brown Moist to Wet (FILL)	6	SS	10		3 16 66 15
					▽ (approx. 244.3)	
		7	SS	9		
242.8 / 8.7	Clayey **SILT**, trace sand to sandy, trace gravel, trace organics Soft to Stiff Brown to Dark Grey Moist to Wet	8	SS	12		

Elevation scale: 251, 250, 249, 248, 247, 246, 245, 244, 243, 242

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m³

Continued Next Page

+³, ×³: Numbers refer to Sensitivity   20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

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RECORD OF BOREHOLE No JV-1

METRIC

GWP# 6304-14-00 | LOCATION Jarvis River Culvert N 5 337 662.6 E 344 844.8 | ORIGINATED BY ES

HWY 61 | BOREHOLE TYPE Hollow Stem Augers/DCPT | COMPILED BY MFA

DATUM Geodetic | DATE 2016.03.19 - 2016.03.20 | CHECKED BY DJP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	DCPT	WATER CONTENT	GR	SA	SI	CL
					241						
		9	SS	7			o				
					240	>100					
		10	SS	4	239		o	4	35	47	14
238.2 / 13.3	**SILT**, trace clay, trace sand Very Loose to Loose Dark Grey Wet					>100					
					238						
		11	SS	2			o				
					237						
		12	SS	4	236		o	0	9	84	7
235.2 / 16.3	**SAND**, some silt, trace gravel, trace clay Very Loose to Dense Grey to Dark Grey Wet				235						
		13	SS	3			o	3	84	11	2
					234						
		14	SS	23	233		o				
					232						

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m3; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 – 5 / 10 (%) STRAIN AT FAILURE

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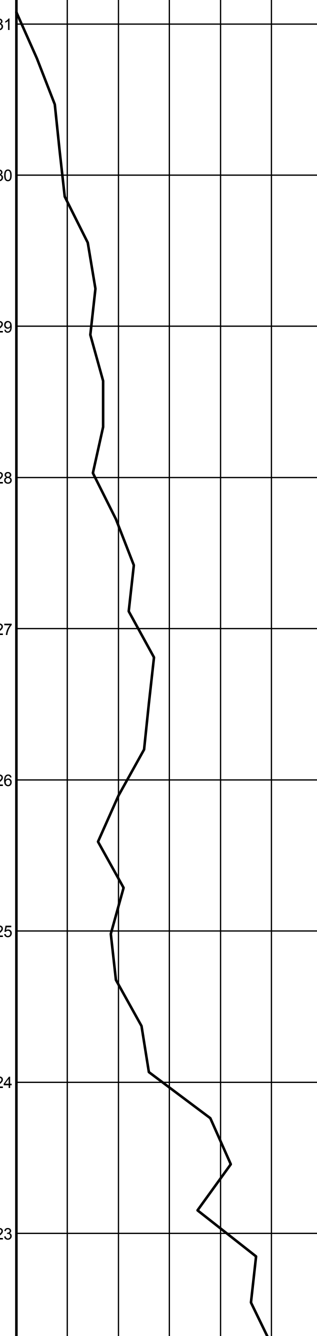
RECORD OF BOREHOLE No JV-1

METRIC

GWP# 6304-14-00
LOCATION Jarvis River Culvert N 5 337 662.6 E 344 844.8
ORIGINATED BY ES

HWY 61
BOREHOLE TYPE Hollow Stem Augers/DCPT
COMPILED BY MFA

DATUM Geodetic
DATE 2016.03.19 - 2016.03.20
CHECKED BY DJP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
231.1			15	SS	33				o		
20.4	End of sampling at 20.4m, begin DCPT						231				
							230				
							229				
							228				
							227				
							226				
							225				
							224				
							223				
222.3											
29.2	END OF DCPT AT 29.2m UPON CONE REFUSAL. WATER LEVEL AT 7.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH										

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 –⊕– 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S 10088.GPJ 2015TEMPLATE(MTO).GDT 7/5/16

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RECORD OF BOREHOLE No JV-1

METRIC

GWP# 6304-14-00 | LOCATION Jarvis River Culvert N 5 337 662.6 E 344 844.8 | ORIGINATED BY ES
HWY 61 | BOREHOLE TYPE Hollow Stem Augers/DCPT | COMPILED BY MFA
DATUM Geodetic | DATE 2016.03.19 - 2016.03.20 | CHECKED BY DJP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	HOLEPLUG AND CUTTINGS TO 0.1m, THEN ASPHALT TO SURFACE.										

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No JV-2

METRIC

GWP# 6304-14-00 LOCATION Jarvis River Culvert N 5 337 682.2 E 344 826.3 ORIGINATED BY ES

HWY 61 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA

DATUM Geodetic DATE 2016.03.20 - 2016.03.20 CHECKED BY DJP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
244.1	GROUND SURFACE							
0.0	**SAND**, trace gravel, trace silt, trace organics Loose Brown Frozen to Wet	1	SS	4	244			
243.5 / 0.6	Clayey **SILT**, some sand, trace gravel, trace organics Soft to Stiff Brown to Grey Moist to Wet	2	SS	7	243			
		3	SS	6	242			
		4	SS	3				0 12 74 14
		5	SS	4	241			
					240	>105 (field vane)		
		6	SS	7				0 16 66 18
	Gravelly **SAND** pocket at 5.1m				239			
238.5 / 5.6	**SILT**, trace sand, trace clay Very Loose to Loose Dark Grey Wet				238			
		7	SS	0	237			
		8	SS	4	236			0 6 86 8
					235			
234.3		9	SS	3				
9.8	END OF BOREHOLE AT 9.8m.							

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No JV-2

METRIC

GWP# 6304-14-00	LOCATION Jarvis River Culvert N 5 337 682.2 E 344 826.3	ORIGINATED BY ES
HWY 61	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY MFA
DATUM Geodetic	DATE 2016.03.20 - 2016.03.20	CHECKED BY DJP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	WATER LEVEL AT 2.2m UPON COMPLETION. Piezometer installation consists of 25.4mm diameter Schedule 40 PVC pipe with a 3.1m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2016.03.21 2.4 241.7 2016.03.22 2.4 241.7										

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S 10088.GPJ 2015TEMPLATE(MTO).GDT 7/5/16

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RECORD OF BOREHOLE No JV-3

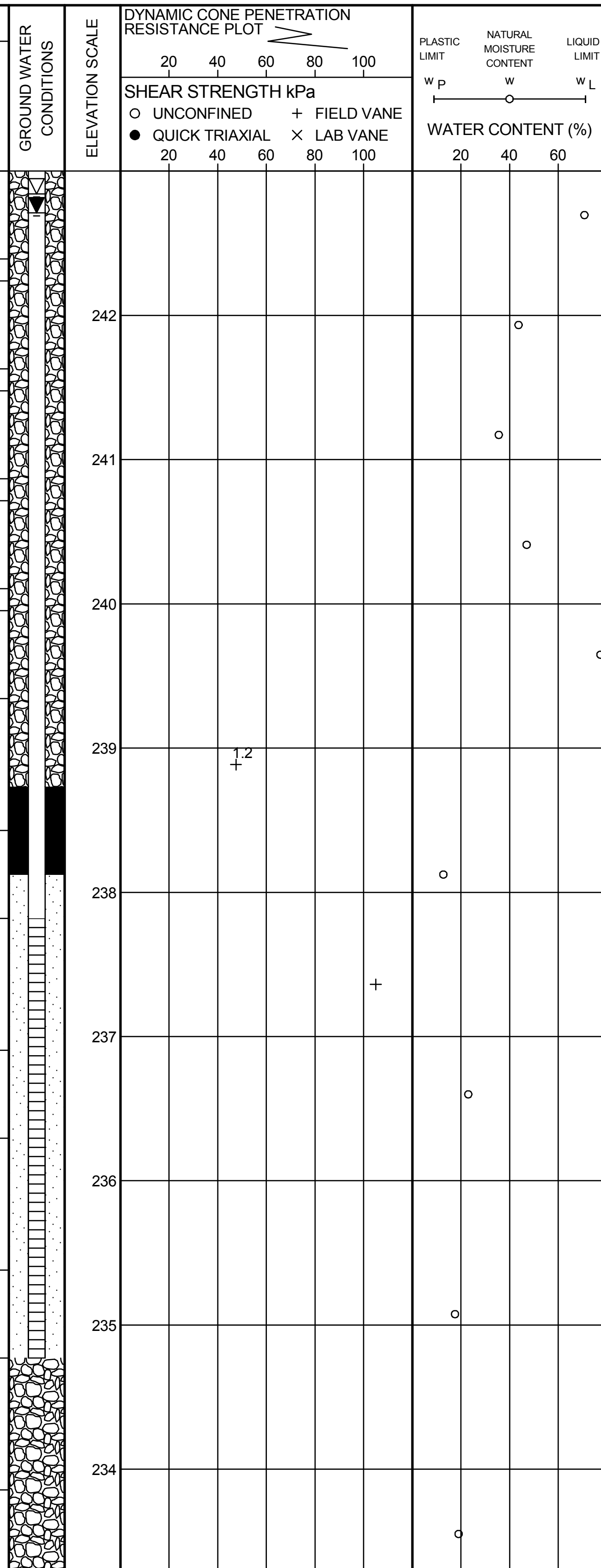
METRIC

GWP# 6304-14-00 | LOCATION Jarvis River Culvert N 5 337 668.9 E 344 869.2 | ORIGINATED BY ES

HWY 61 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY MFA

DATUM Geodetic | DATE 2016.03.19 - 2016.03.19 | CHECKED BY DJP

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
243.0	GROUND SURFACE					
0.0	Clayey **SILT**, trace sand, trace organics Very Soft to Firm Brown Moist to Wet	1	GS			
		1	SS	4	242	
		2	SS	1	241	0 9 64 27
		3	SS	1	240	
		4	SS	3	239	
238.9 4.1	**SILT**, trace sand, trace clay Loose Grey Wet	5	SS	4	238	
		6	SS	7	237	
236.0 7.0	**SAND**, some silt to silty, trace gravel, trace clay Loose Dark Grey Wet	7	SS	8	236 235	2 74 22 2
		8	SS	7	234	
233.2 9.8	END OF BOREHOLE AT 9.8m.					



UNIT WEIGHT γ kN/m³

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S 10088.GPJ 2015TEMPLATE(MTO).GDT 7/5/16

RECORD OF BOREHOLE No JV-3

METRIC

GWP#	6304-14-00	LOCATION	Jarvis River Culvert N 5 337 668.9 E 344 869.2	ORIGINATED BY	ES
HWY	61	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	MFA
DATUM	Geodetic	DATE	2016.03.19 - 2016.03.19	CHECKED BY	DJP

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	WATER LEVEL AT 0.2m UPON COMPLETION. Piezometer installation consists of 25.4mm diameter Schedule 40 PVC pipe with a 3.1m slotted screen.										

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2016.03.20	0.2	242.8
2016.03.21	0.2	242.8
2016.03.22	0.3	242.7

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 - 5 / 10 (%) STRAIN AT FAILURE

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Appendix B

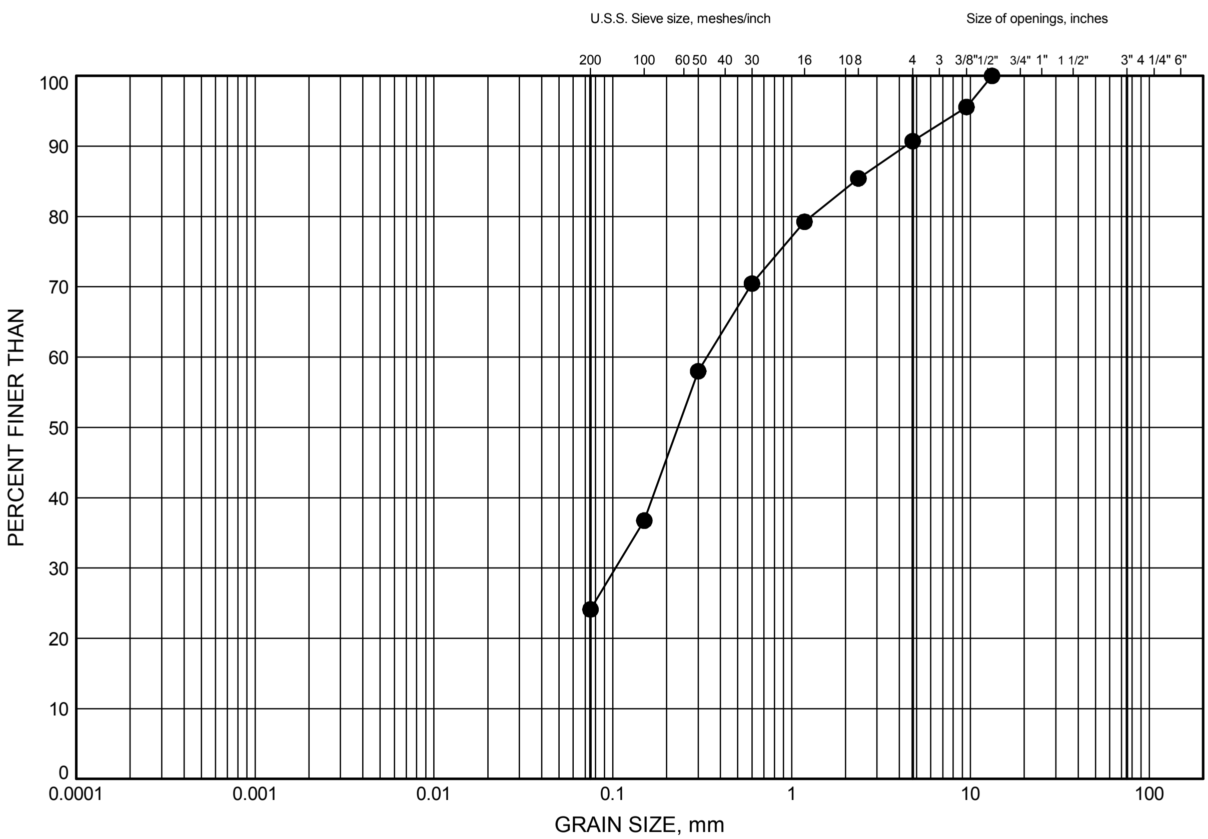
Laboratory Test Results

Jarvis River Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	JV-1	1.83	249.67

Date July 2016

GWP# 6304-14-00

THURBER

Prep'd MFA

Chkd. DJP

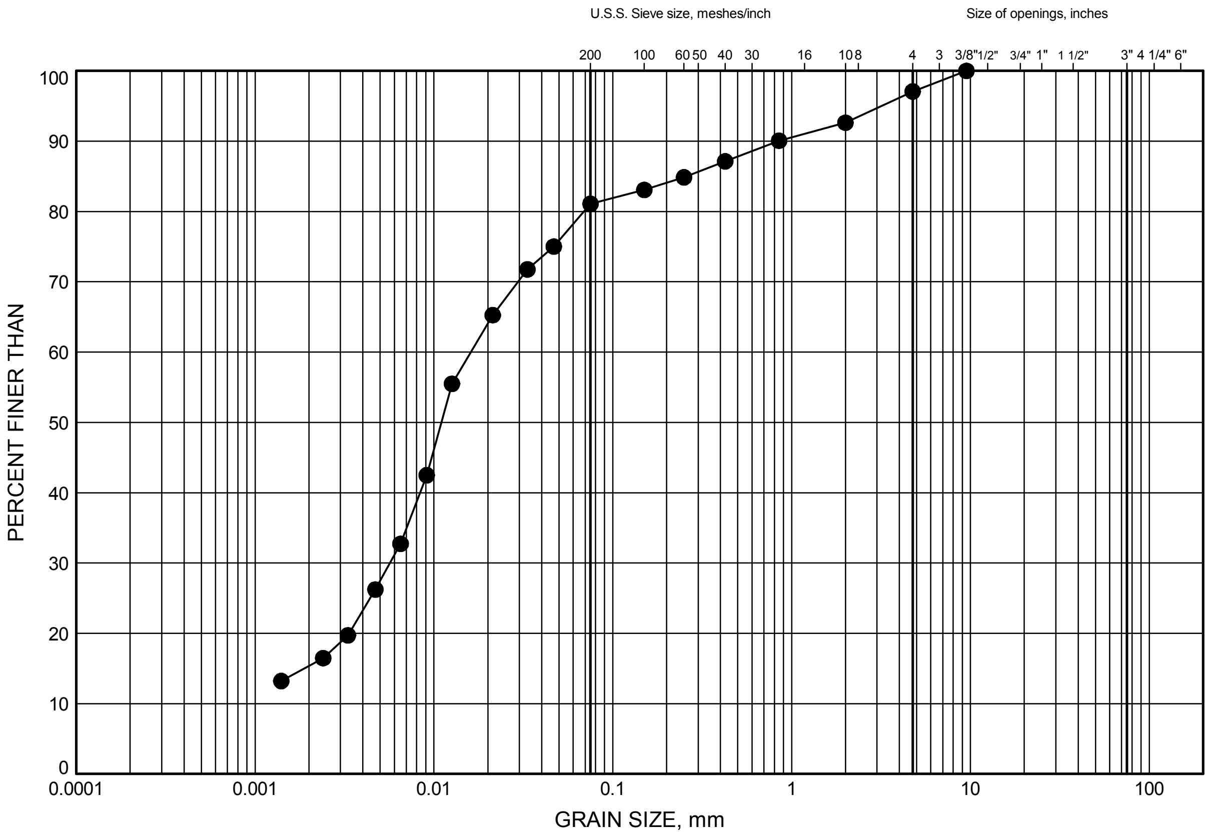
GRAIN SIZE DISTRIBUTION - THURBER 10088.GPJ 7/5/16

Jarvis River Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B2

Clayey SILT FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	JV-1	6.40	245.10

GRAIN SIZE DISTRIBUTION - THURBER 10088.GPJ 7/5/16

Date July 2016

GWP# 6304-14-00

THURBER

Prep'd MFA

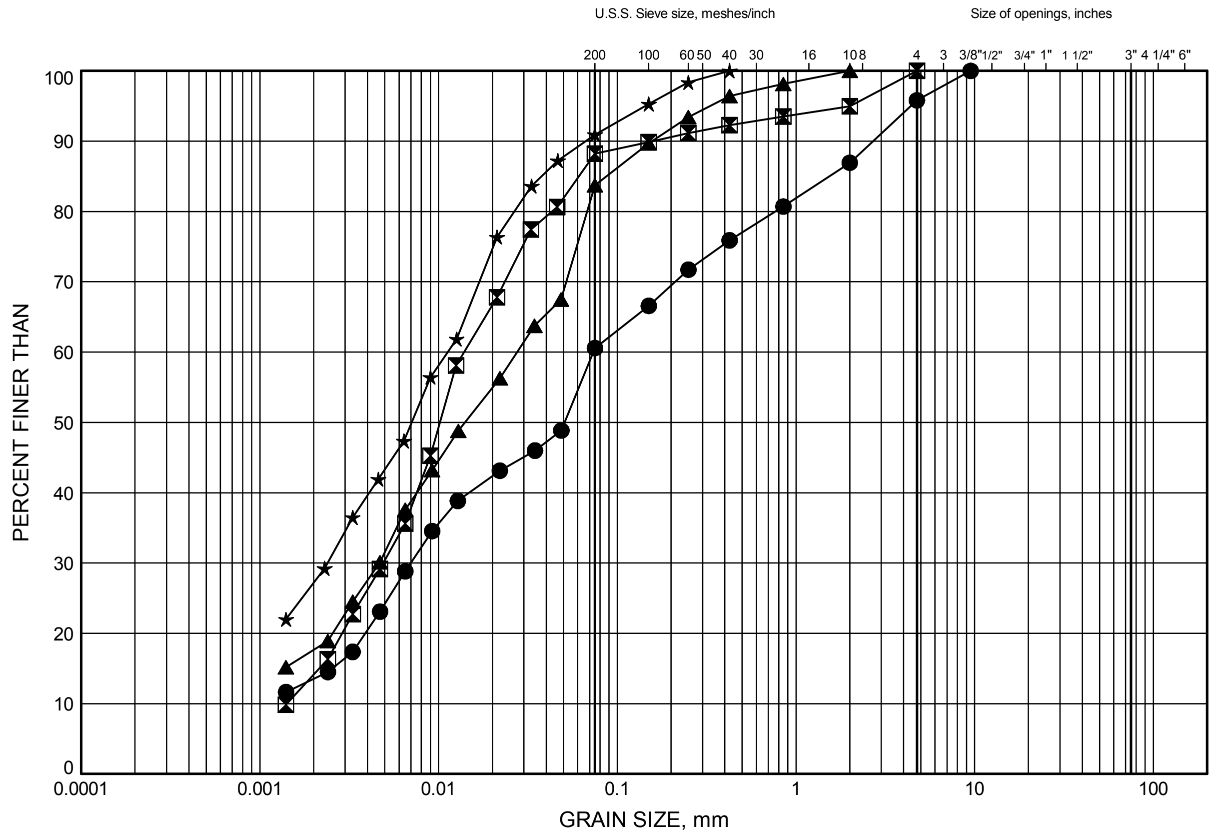
Chkd. DJP

Jarvis River Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B3

Clayey SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	JV-1	12.50	239.00
⊠	JV-2	2.59	241.51
▲	JV-2	4.81	239.29
★	JV-3	1.83	241.17

Date July 2016

GWP# 6304-14-00

THURBER

Prep'd MFA

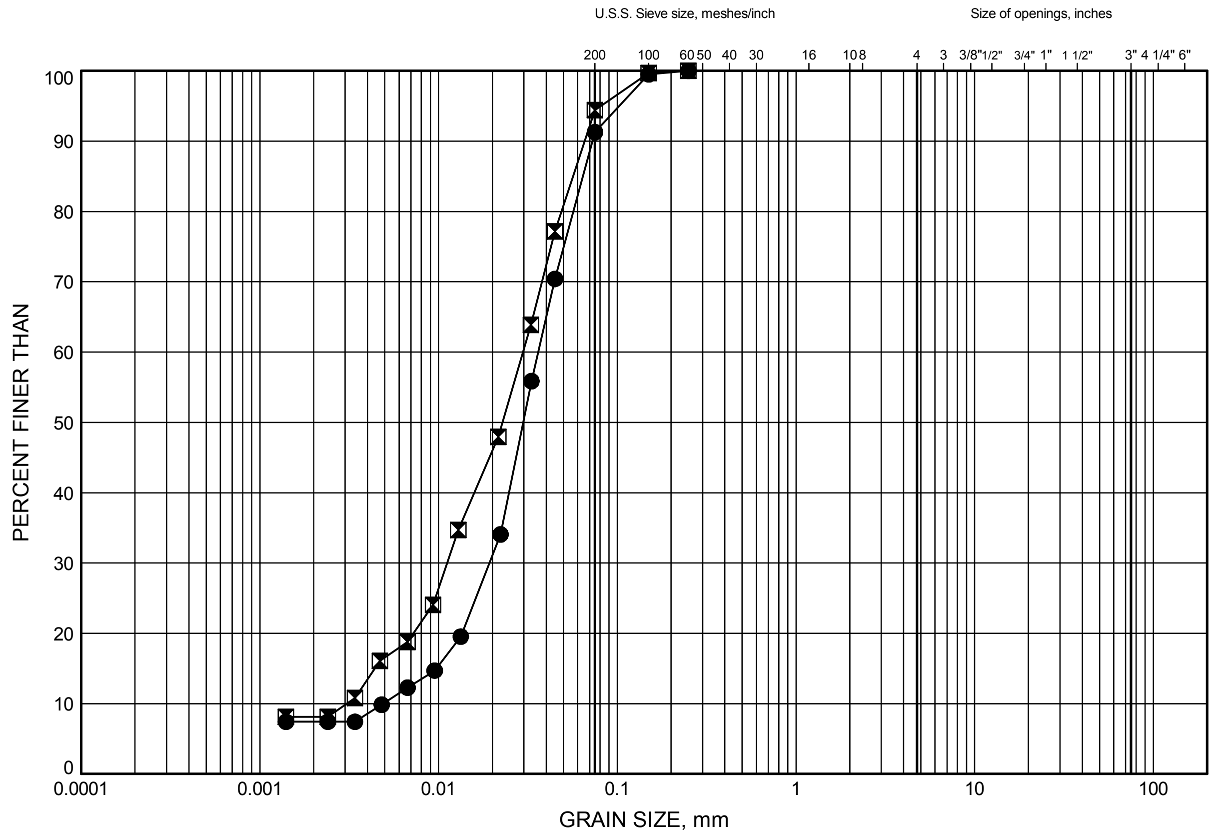
Chkd. DJP

Jarvis River Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B4

SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	JV-1	15.54	235.96
⊠	JV-2	7.92	236.18

Date July 2016

GWP# 6304-14-00

THURBER

Prep'd MFA

Chkd. DJP

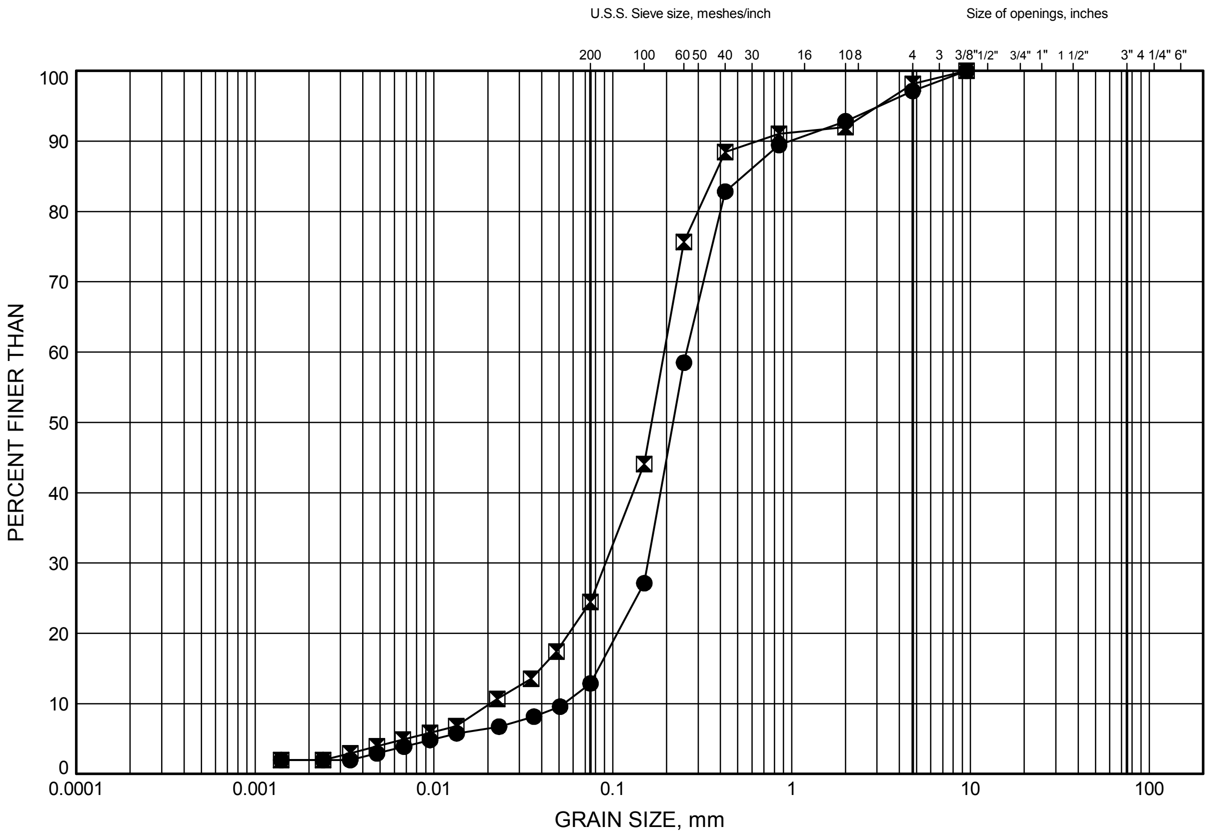
GRAIN SIZE DISTRIBUTION - THURBER 10088.GPJ 7/5/16

Jarvis River Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B5

SAND to Silty SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	JV-1	17.07	234.43
⧗	JV-3	7.92	235.08

GRAIN SIZE DISTRIBUTION - THURBER 10088.GPJ 7/5/16

Date July 2016

GWP# 6304-14-00

THURBER

Prep'd MFA

Chkd. DJP

THURBER

Appendix C

Selected Site Photographs

THURBER

Photograph 1: Looking Southeast

Photograph 2: Looking Northeast

THURBER

Photograph 3: Culvert Inlet

Photograph 4: Culvert Outlet

THURBER

Photograph 5: West Embankment Slope

Photograph 6: East Embankment Slope

THURBER

Appendix D

Borehole Locations and Soil Strata Drawings

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No 2016-6249
GWP No 6304-14-00

HIGHWAY 61
JARVIS RIVER
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

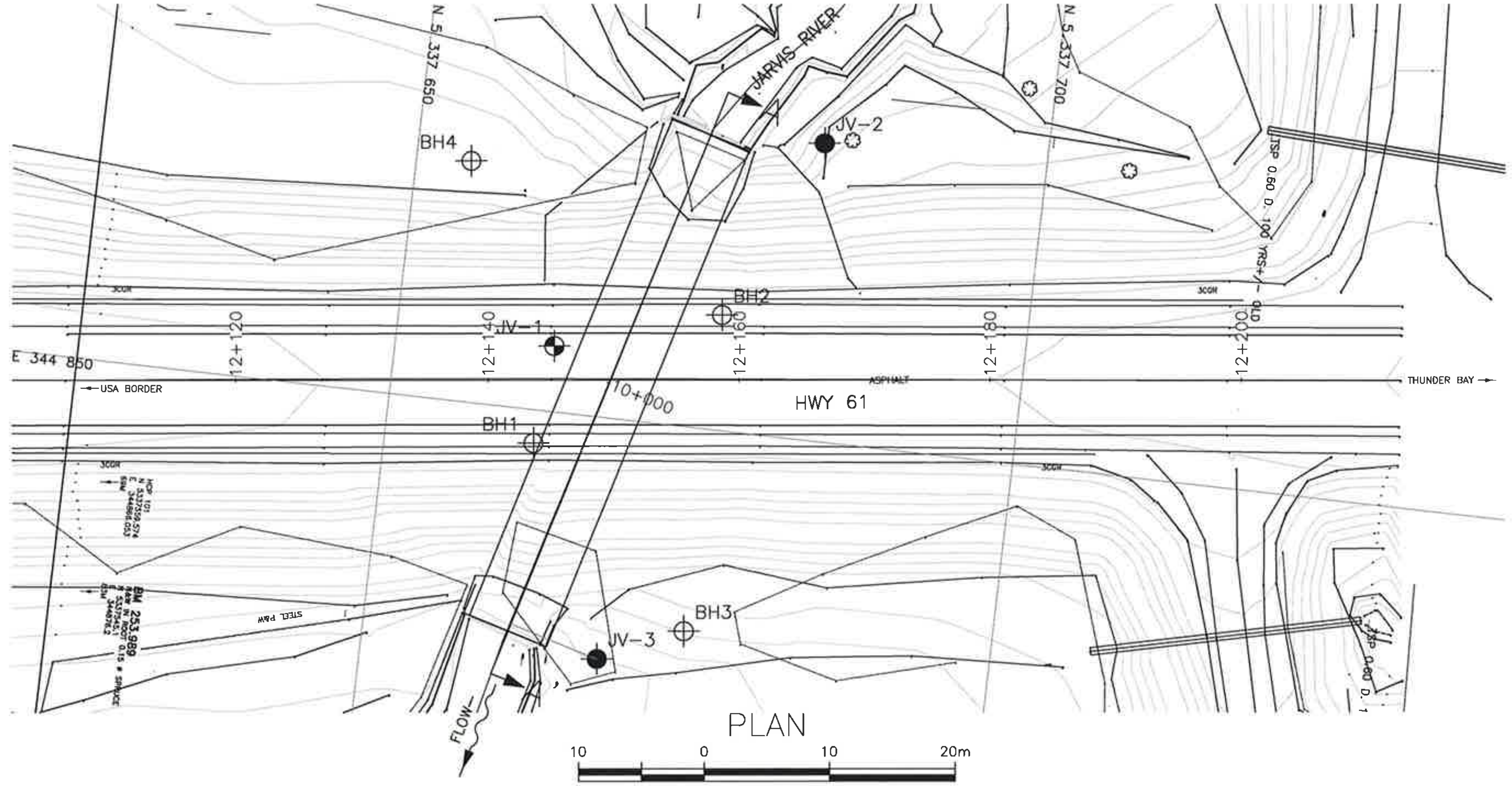
SHEET 4

HATCH

THURBER ENGINEERING LTD.

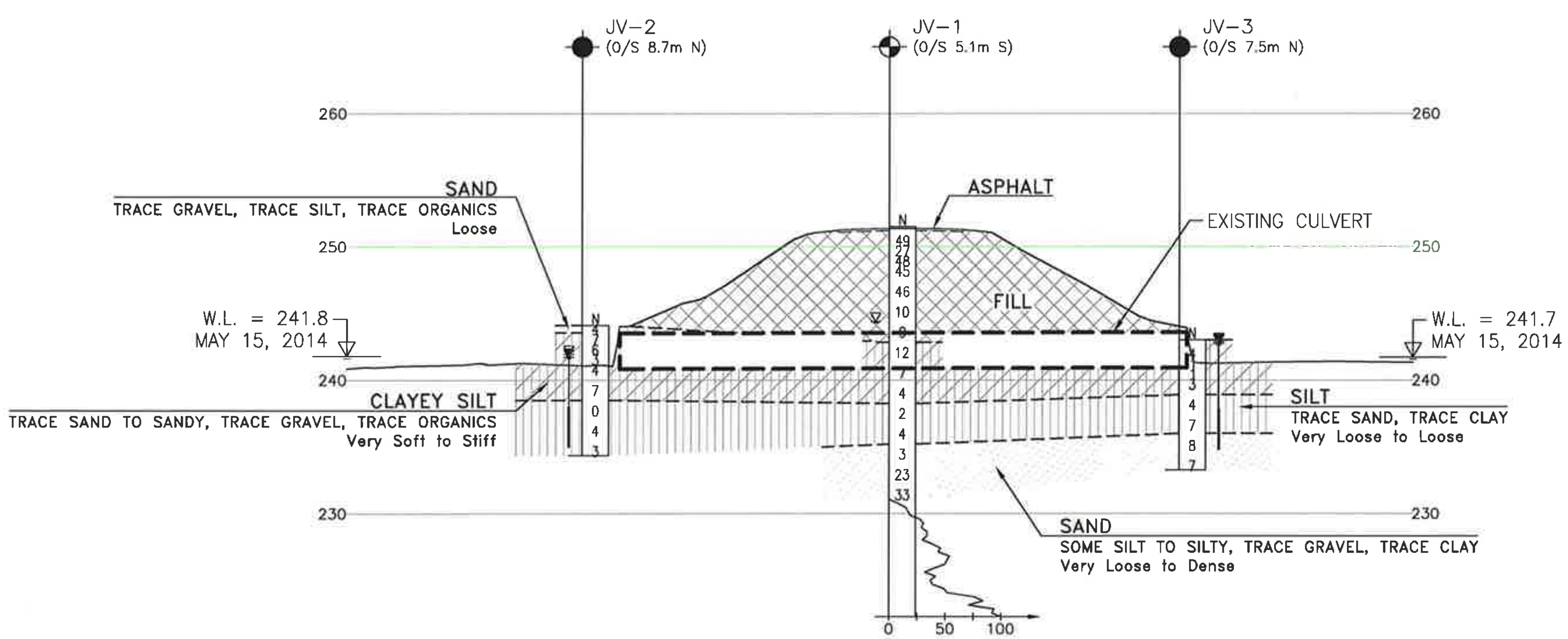
LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Oct 26/16
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
K. L. SIN
100141639
Oct 26/16
PROVINCE OF ONTARIO



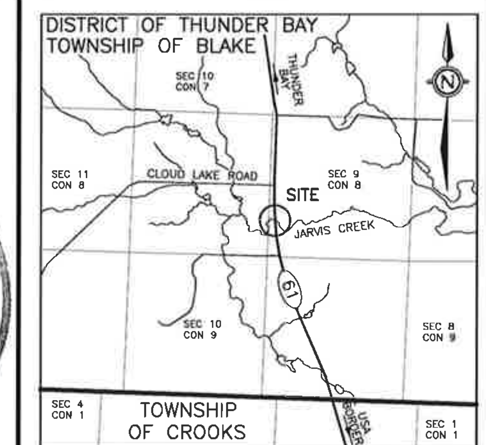
PLAN

SCALE 1:500



SECTION ALONG ℄ CULVERT A–A'

SCALE 1:500



KEYPLAN

LEGEND

●	Borehole
⊕	Borehole and Cone
⊕	Borehole by Others
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
▼	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
BH1	251.0	5 337 663.7	344 852.5
BH2	251.0	5 337 677.4	344 840.6
BH3	244.2	5 337 677.3	344 866.0
BH4	245.1	5 337 656.2	344 830.7
JV-1	251.5	5 337 662.6	344 844.8
JV-2	244.1	5 337 682.2	344 826.3
JV-3	243.0	5 337 668.9	344 869.2

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 52A-223

REVISIONS	DATE	BY	DESCRIPTION		
DESIGN DJP	CHK AMP	CODE	LOAD	DATE OCT 2016	
DRAWN MFA	CHK DJP	SITE	STRUCT	DWG 3	

FILENAME: H:\Drafting\10000\10088\ED-10088-PLPR-JV.dwg
PLOTDATE: 10/25/2016 1:25 PM

THURBER

Appendix E

Subsurface Information from Preliminary Foundation Report
DST Ltd. Report, Geocres No. 52A-192

RECORD OF BOREHOLE No BH1

METRIC

W.P. 6013-E-0023 LOCATION Jarvis River Culvert Hwy 61: STA. 12+170, 5.0m RT ORIGINATED BY PR

DIST Thunder Bay HWY 61 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY MD

DATUM LOCAL DATE 2014 08 28 CHECKED BY DB

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
107.0	GROUND SURFACE						
106.9 / 0.1	ASPHALT						
106.7 / 0.3	FILL - SAND-some grave, trace silt	AS1	AS				
	FILL-SAND - some to with gravel, some silt, cobbles, BROWN□L□□S□ □□□□S□	SS2	SS	10		106	
		SS3	SS	13		105	
		SS4	SS	8		104	
		SS5	SS	40		103	
		SS6	SS	25			
		SS7	SS	16		102	39 43 (18)
		SS8	SS	35		101	
99.4 / 7.6	SILT-Clayey to trace clay, trace to some sand, trace gravel, STI□□, BROWN	SS9	SS	12	∇	100 / 99	
		SS10	SS	35		98	
	-BROWN/BLACK	SS11	SS	59		97	
96.7 / 10.3	END OF BOREHOLE Auger Refusal Possible Boulder						

Column headings also include: STRAT PLOT; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

NR = NO RECOVERY $+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No BH2

METRIC

W.P. 6013-E-0023	LOCATION Jarvis River Culvert Hwy 61: STA. 12+185, 5.2m LT		ORIGINATED BY PR
DIST Thunder Bay HWY 61	BOREHOLE TYPE Hollow Stem Auger 80 mm		COMPILED BY MD
DATUM LOCAL	DATE 2014 08 28		CHECKED BY DB

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (20, 40, 60, 80, 100): ○ UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
106.9	GROUND SURFACE								
106.8 / 0.1	ASPHALT								
106.6 / 0.3	FILL - SAND- some gravel, trace silt	AS1	AS						
	FILL-SAND-Some silt to silty, some gravel, cobbles, BROWN□C□MPACT □□□□S□	SS2	SS	25		19	61	(20)	
		SS3	SS	32					
		SS4	SS	34					
		SS5	SS	25					
		SS6	SS	36					
		SS7	SS	14					
100.8 / 6.1	SILT-Clayey to trace clay, trace to some sand, trace gravel, GREY/DARK GREY, STIFF	SS8	SS	8		3	11	71	15
		SS9	SS	10					
	□□□□□ □r□□□□□	SS10	SS	7		0	10	60	30
	-DARK GREY	SS11	SS	31	▽				
		SS12	SS	3		0	3	87	10
		SS13	SS	2					
		SS14	SS	2					
89.7		SS15	SS	2		0	2	90	8
17.2	END OF BOREHOLE								

ELEVATION SCALE: 106, 105, 104, 103, 102, 101, 100, 99, 98, 97, 96, 95, 94, 93, 92, 91, 90

NR = NO RECOVERY $+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No BH3

METRIC

W.P. 6013-E-0023 | LOCATION Jarvis River Culvert Hwy 61: STA. 12+182, 20.0m RT | ORIGINATED BY PR

DIST Thunder Bay HWY 61 | BOREHOLE TYPE Hollow Stem Auger 80 mm | COMPILED BY MD

DATUM LOCAL | DATE 2014 09 02 | CHECKED BY DB

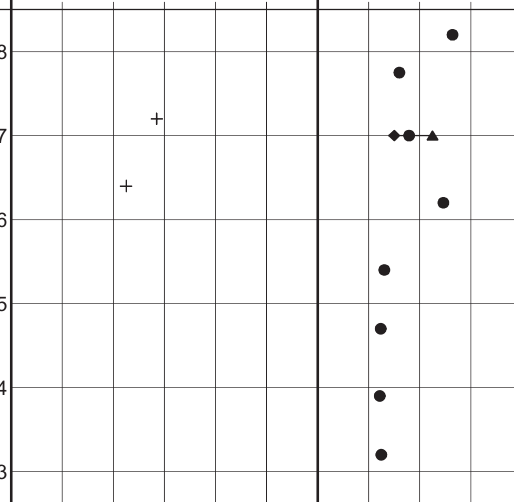
ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
98.5	GROUND SURFACE						
98.3	TOPSOIL	AS1	AS				
0.2	SILT-Clayey to trace clay, GREY/DARK GREY, FIRM to STIFF [illegible]					98	
		SS2	SS	3			
		SS3	SS	2		97	
		SS4	SS		▽	96	
		SS5	SS	2		95	
		SS6	SS	2			0 1 86 13
		SS7	SS	4		94	
		SS8	SS	2		93	
92.6 / 5.9	END OF BOREHOLE						

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³



NR = NO RECOVERY +3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

ON_MOT GS-TB-019499 - JARVIS RIVER HWY 61_BHLOGS.GPJ DST_MIN.GDT 11/18/14

RECORD OF BOREHOLE No BH4

METRIC

W.P. 6013-E-0023 | LOCATION Jarvis River Culvert Hwy 61: STA. 12+165, 17.5,m LT | ORIGINATED BY PR

DIST Thunder Bay HWY 61 | BOREHOLE TYPE Hollow Stem Auger 80 mm | COMPILED BY MD

DATUM LOCAL | DATE 2014 09 04 | CHECKED BY DB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
99.0	GROUND SURFACE					
98.9 / 0.1	TOPSOIL					
	SILT-Clayey to trace clay, some sand, trace gravel, S□□T □□ STI□□□BROWN/DARK GREY	SS1	SS	5		
		SS2	SS	9		98
	-DARK GREY				∇	
		SS3	SS	8		97
	□Tr□□ W□□d	SS4	SS	3		96
		SS5	SS	3		95
		SS6	SS	11		
		SS7	SS	5		94
93.1		SS8	SS	11		
5.9	END OF BOREHOLE					

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, □ QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

NR = NO RECOVERY

$+^3, \times^3$: Numbers refer to Sensitivity

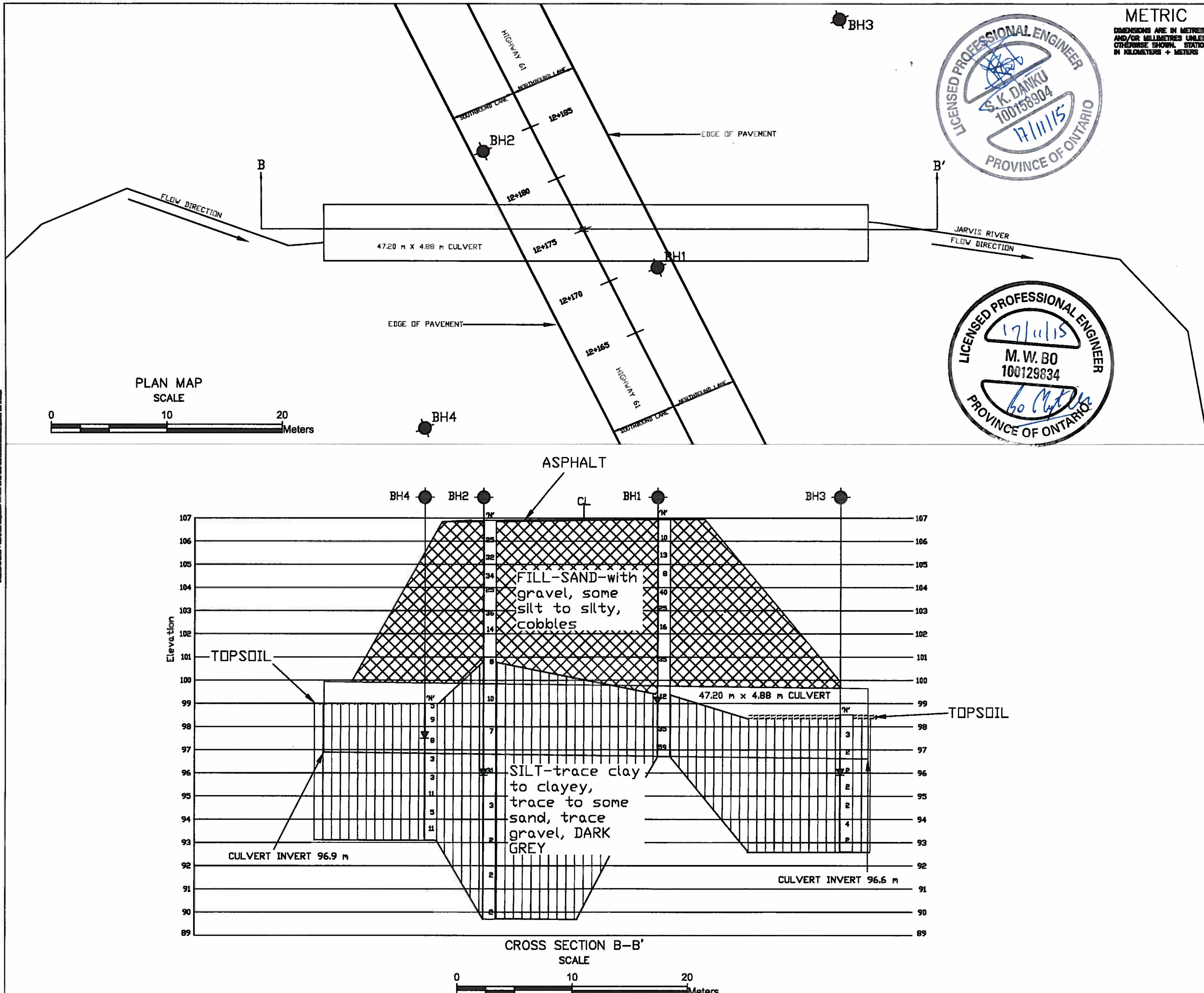
○ 3% STRAIN AT FAILURE

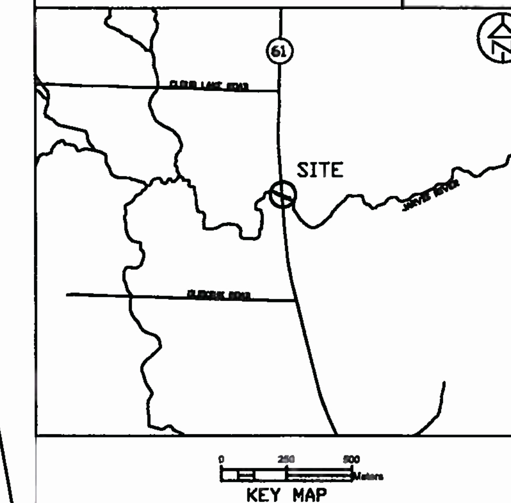
CONT	No
GWP	No 6304–14–00
SITE	No 48W–183/C
GEOCRES	No 52A–192

CULVERT REPLACEMENT
JARVIS RIVER CULVERT
STA 12+165 TO STA 12+185
Survey________ Revised________

SHEET

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETERS + METERS





LEGEND

- Borehole
- 'N' Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation

Fill, Organics, Topsoil, Till, Bedrock, Sand, Silt, Clay, Sand & Gravel, Boulders

No.	Elevation	Northing	Easting	Station	Offset
BH1	107.0	5338849 m N	317024 m E	12+170	5.0 m RT
BH2	106.9	5338866 m N	317014 m E	12+185	5.2 m LT
BH3	98.5	5338856 m N	317047 m E	12+182	20.0 m RT
BH4	99.0	5338854 m N	317000 m E	12+165	17.5 m LT

NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

DST Consulting Engineers Inc.
605 Hewitson Street
Thunder Bay, ON P7B 5V5
Ph: (807) 623-2929
Fx: (807) 623-1792
Email: thunderbay@dstgroup.com

DRAWING 2

Appendix F

Comparison of Foundation Alternatives

THURBER

COMPARISON OF FOUNDATION ALTERNATIVES

Concrete Box Culvert	Concrete or Corrugated Steel Pipe Culvert	Concrete Open Footing Culvert	Concrete or Steel Pipe installed by Trenchless Method
Advantages: i. Ease of construction. ii. Lower requirement for soil geotechnical resistances as loading is spread over a larger width. ***Disadvantages:*** i. Require excavation of existing embankment exceeding 10 m in height. ii. Significant temporary roadway protection is needed to maintain highway traffic. iii. Extensive construction dewatering is necessary for culvert base below river level.	***Advantages:*** i. Ease of construction. ii. Geotechnical resistance is not a concern. ***Disadvantages:*** i. Steel pipes have shorter design life than concrete culverts. ii. Multiple pipes may be required to satisfy hydraulic demands. iii. Significant temporary roadway protection is needed to maintain highway traffic.	***Advantages:*** i. Ease of construction. ii. May have less environmental issues. ***Disadvantages:*** i. Requires higher soil geotechnical resistances to support strip footings. ii. Requires deeper excavation for strip footing construction. iii. Potentially more difficult dewatering requirements.	***Advantages:*** i. Short construction time if appropriate method is used. ii. May have less environmental issues. iii. No significant excavation needed other than spoil removal and construction of entry/exit pits. iv. Minimal dewatering requirement. v. No disruption to traffic. ***Disadvantages:*** i. May cause pavement settlement and cracking. ii. Difficulty in alignment control if obstructions are encountered. iii. Excavation and dewatering required for entry/exit pits.
FEASIBLE	**RECOMMENDED**	**NOT RECOMMENDED**	**RECOMMENDED**

THURBER

Appendix G

- **List of Standard Specifications**
- **Suggested NSSP Wording**
- **NSSP – Pipe Installation by Trenchless Methods**

1. List of OPSS and OPSD Documents Relevant to this Project

- OPSS PROV 206
- OPSS PROV 422
- OPSS PROV 501
- OPSS PROV 517
- OPSS PROV 518
- OPSS PROV 539
- OPSS PROV 804
- OPSS PROV 902
- OPSS PROV 1010
- OPSS PROV 1205
- OPSD 802.034
- OPSD 803.010
- OPSD 803.031
- OPSD 810.010

2. Suggested NSSP Wording

- Suggested Text for NSSP on "Obstructions"

Excavation and installation of cofferdams and roadway protection systems or temporary shoring for entry and exit pits could encounter obstructions such as cobbles or boulders embedded in the fill and native soils. Such obstructions may impede excavation progress and/or shoring installation. The contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.

- Suggested Text for NSSP on "Groundwater and Dewatering"

The contractor is notified that the site may be prone to high groundwater levels and that these levels may be higher than the water levels shown in the Foundation Investigation Report prepared for this site. While reference should be made to that report for a description of the encountered conditions, the contractor must satisfy himself regarding the groundwater levels likely to prevail at the time of construction and be prepared to implement dewatering procedures.

The contractor is further notified that failure to implement dewatering in advance of excavating below the groundwater table may result in sloughing and boiling of the soil in the excavation and a loss in stability and bearing resistance.

Design and provision of an effective dewatering system is the responsibility of the contractor. Subgrade preparation, culvert construction and backfilling must be carried out in the dry.

3. NSSP – Pipe Installation by Trenchless Methods

Attached.

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Non Standard Special Provision	January 2012

1. SCOPE

This specification covers the general requirements for the installation of pipes by trenchless methods.

The Contractor shall determine the most appropriate method of installation. Specifications for Jack and Bore, Pipe Ramming, Directional Drilling, and Tunnelling are provided herein, and shall be applied to the installation method considered feasible by the Contractor.

OPSS 415 (Construction Specification for Pipeline and Utility Installation by Tunnelling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling) shall not be used to do the work for the above tender item.

2. REFERENCES

This specification refers to the following standards, specifications, or publications:

Foundation Investigation Report, Jarvis River Culvert Replacement, Highway 61, Township of Blake, Thunder Bay District, Ontario, GWP 6304-14-00, Site No. 48W-183/C, by Thurber Engineering Ltd., Reference No. 10088.

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

OPSS 504	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 507	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures in Open Cut
OPSS 514	Trenching, Backfilling, and Compaction
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 538	Support Systems
OPSS 539	Protection Schemes

Ontario Provincial Standard Specifications, Material

OPSS 1004	Aggregates - Miscellaneous
OPSS 1350	Concrete - Materials and Production
OPSS 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe

MTO Specifications

OPSS 1820	Material Specification for Circular Concrete Pipe
OPSS 1840	Material Specification for Non-Pressure Polyethylene Plastic Pipe Products

American Society for Testing and Materials (ASTM) International Standards

ASTM A252-93	Welding and Seamless Steel Pipe Piles
ASTM D2657-03	Standard Practice for Heat Fusion Joining of Polyelofin Pipe and Fittings
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F894	Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

Canadian Standards Association Standards:

CSA B182.6	Profile Polyethylene Sewer Pipe and Fittings.
CAN/CSA A5-93	Portland Cement
CSA W59	Welded Steel Construction (Metal Arc Welding)

3. DEFINITIONS

For the purpose of this specification, the following definitions apply:

Backreamer: a cutting head suitably designed for the subsurface conditions that is attached to the end of a drill string to enlarge the pilot bore during a pullback operation.

Bore Path: a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Design Engineer: means the Engineer retained by the Contractor who produces the original design and working drawings. The design engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer: means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario.

Digger Shield/Hand Mining: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead while tunnelling advances using hand–mining (man-entry operation or "Jack and Mine) or a "digger" type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Drilling Fluids: a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Fracture or Frac Out: a condition where the drilling fluid's pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/or rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

Engineer: a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

Excavation: includes all materials encountered regardless of type and extent. Excavation shall include removal of natural soil, large boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA): areas adjacent to construction that are off limits to the Contractor as specified elsewhere in the Contract.

Fill: man-made mixture of previously placed/handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Grouting: injection of grout into voids.

Guidance System: an electronic system capable of locating the position, depth and orientation of the drill head during the directional drilling process.

Directional Drilling (DD): directional boring or guided boring.

HDPE: high density polyethylene.

Inadvertent Returns: the flow of unexpected fluids, saturated materials (or running soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Jack and Bore: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore.

Loss of Circulation: the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Pilot Bore: the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking: a method for installing steel casing or concrete pipe in the subsurface utilizing hydraulically operated jacks of adequate number and capacity to ensure smooth and uniform advancement without overstressing the liner/pipe.

Pipe Ramming: a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Primary Liner (Support): system installed prior to or concurrent with excavation, to maintain stability of an excavation and to support earth or rock and any structure utilities or other facilities in or on the supported earth or rock mass, until the excavation is completed.

Product: pipe culverts, pipe sewers, watermain pipe and sanitary pipe.

Pullback: that part of the DD method in which the drill string is pulled back through the bore path to the entry point.

Quality Verification Engineer (QVE): an Engineer who has a minimum of five (5) years experience in the field of pipe installation using trenchless methods or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and to issue Certificate(s) of Conformance.

Reaming: a process for pulling a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This typically includes multiple passes.

Rock: natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a size equivalent to 0.3 m in diameter or greater.

Secondary Liner: concrete pipe, HDPE pipe or un-reinforced cast-in-place concrete, installed subsequent to tunnel excavation.

Shaft: vertically sided excavation used as entry and/or exit points from which the trenchless method is initiated or directed for the installation of product.

Strike Alert: a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry: a mixture of soil and/or rock cuttings, and drilling fluid.

Soil: all materials except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 m in diameter.

Tunnelling: an underground method of constructing a passage open at both ends that involves installing a pipe.

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

The Contractor’s documentation, submission requirements and installation methods shall specifically consider and address the subsurface conditions at each pipe crossing as identified in the Foundation Investigation Report.

4.02 Working Drawings

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one (1) week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

As a minimum, working drawings/details pertaining to the tunnel design and construction shall include the following (as appropriate):

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;
- A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails;
- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:

- Primary liner design details, if applicable; and
- Design assumption and material data when materials other than those specified are proposed for use.
- Drill path design, details of alignment and alignment control, maximum curvature and reaming stages;

c) Materials:

- Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application; and
- Material mixture for filling voids and installation procedures.

d) Upstream/Downstream Portal Installation Procedure:

- The access shaft or entry/exit pit details designed and stamped/signed by the Design Engineer, as applicable; and
- Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

- Excavation and pipe jacking procedures, including methodology to handle obstructions and preventing soil cave-in; and
- Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water.

g) Monitoring Method

- The methods to be employed to monitor and maintain the alignment of the installation;

4.03 Site Survey

Prior to commencing the work, the Contractor shall, at each pipe location, layout the alignment and install settlement monitoring points.

4.04 Certificate of Conformance

The Contractor shall submit details of the sequence and method of construction to the Quality Verification Engineer for review, prepared and stamped by the Design Engineer. The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

Site Surveying (as noted in Section 4.02)
Excavation for pits including dewatering of excavation
Jacking/Ramming/Directional Drilling of Casing/Liner
Excavation and Dewatering
Installation of the Product
Grouting Operations

Each Certificate of Conformance shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a **final** Certificate of Conformance sealed and signed by the Quality Verification Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

The Design Engineer will not be permitted to carry out the work of the Quality Verification Engineer.

5. MATERIALS

5.01 Product

The product shall be concrete pipe or high density polyethylene pipe as specified.

5.02 Concrete

Concrete shall be according to OPSS 1350. The concrete strength shall be as specified in the Contractor's design submission.

5.03 Concrete Reinforcement

Steel reinforcing for concrete work shall be according to OPSS 1440.

5.04 Timber

Timber shall be sound, straight, and free from cracks, shakes and large or loose knots.

5.05 Grout

The Contractor shall submit the proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces. Purging grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA A5-93 and two parts mortar sand conforming to OPSS 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Jack and Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-95 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS 1820.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

Steel pipe shall conform with ASTM A 252-93 welded joints.
New steel casing when specified shall be smooth wall carbon steel pipe according to ASTM A252-93 Grade 2.

Used steel casing can be used provided that the steel casing can resist the applicable static and dynamic loadings.

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. A minimum wall thickness of 50 mm and minimum yield strength of 240 MPa is required.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

Steel casing pipe shall have roundness such that the difference between the major and minor outside diameters shall not exceed 1% of the specified nominal outside diameter or 6 mm, whichever is less.

Steel casing pipe shall have a minimum allowable straightness of 1.5 mm maximum per metre of length.

5.07.02 Mill Certificates

For permanent casing, the Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for casings.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date and the signature of an authorized officer of the Canadian testing laboratory.

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions.

5.08.02 Pipe Materials

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be suitable for and compatible with the class and type of pipe with which they will be used and in according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) of the HDPE pipe to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

The Contractor's submission shall demonstrate, in conjunction with the manufacturer's specifications, that the heat resistance of the pipe material is sufficient to tolerate without damage the heat of hydration generated by grout curing.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner to provide support and stability to the excavation.

5.09.02 Secondary Liner

Concrete or High Density Polyethylene Pipe shall be used according to the following requirements.

5.09.02.01 Concrete Pipe

Concrete pipe as per OPSS 1820 shall be used. The Contractor shall select the pipe class to withstand grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.09.02.02 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials shall be completed using flanged connections.

6. EQUIPMENT

6.01 Jack & Bore Equipment

Jack & bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.02 Pipe Ramming Equipment

Pipe ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the drive pit through the existing subsurface conditions at the site.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.03 Directional Drilling Equipment

6.03.01 General

The directional drilling equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system of sufficient capacity to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The directional drilling rig shall:

- consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head;
- contain a guidance system to accurately guide boring operations;
- be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation; and
- be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling Equipment

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the tunnel face shall be submitted to the Contract Administrator information purposes. Use of explosives or rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use.

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation shall be subject to the limitations presented in the following subsections.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system at every 5 m in normal conditions and every 2 m where precise alignment control is necessary;

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

All excavations shall be carried out in accordance with the Occupational Health and Safety Act (OHSA) of Ontario.

For directional drilling, the contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor’s sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.01.02 Shafts

Shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS 539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA's may be impaired due to the method of operation, protection shall be provided. Protection systems include primary liner and portal excavation support systems. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contract, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 504.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 514.

7.01.09 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.10 Removal of Boulders

The Contractor is alerted that cobbles and boulders should be anticipated in the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.11 Record Keeping

Verification record requirements of the alignment and depth of the installation shall be as specified in the Contract Documents. A copy of the verification records shall be given to the Contract Administrator at the completion of the installation.

7.01.12 Testing

Testing of the product installation shall consist of verifying the specified grade between the two ends of the pipe and passing of water from the median end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.13 Management and Disposal of Excess Material

Management and disposal of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.14 Site Restoration

Site restoration shall be according to OPSS 507.

7.01.15 Supervision

A qualified individual, who is experienced in the pipe installation by trenchless methods shall supervise the work at all times.

7.02 Jack and Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

- Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.

- Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavation shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavation shall be filled with grout.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. But welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement without overstressing of the pipe. Delays shall be avoided between ramming operations.

A ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.

Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator. Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed. The annular space between the liner pipe and the product shall be fully grouted with a water tight, expandable and stable grout.

7.04 Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

7.04.02 Site Preparation

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for DD operations are to be made. All activities shall be confined to designated work areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor's submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor's methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback and re-drill from the location along the bore path before the deviation.

In the event that a drilling fluid fracture, inadvertent returns, or loss of circulation occurs during pilot bore drilling operations, the Contract Administrator shall be advised of the event and action shall be taken in accordance with the Contractor's submitted contingency plan.

At the entry and exit points, there is potential for ravelling of the existing soil, fill and or weathered rock areas along the alignment. This is conventionally addressed by the use of drilling fluid. However, casing may be required. The Contractor's methods shall take into consideration the potential need to install sections of casing to manage ravelling at or near ground surface.

If a drill hole beneath the highway must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence.

The Contractor shall maintain drilling fluid pressure and circulation throughout the DD process, including during the initial pilot bore and during the reaming process.

The Contractor shall at all times and for the entire length of the installation alignment be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates and pressures.

7.04.04 Drilling Fluid Fracture (Frac-Out)

In order to reduce the potential for hydraulic fracturing of the hole during directional drilling, a minimum depth of cover of 5m is normally maintained between the pipe and the ground surface. Sections of the pipe close to the exit pit with less than 5m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled to prevent frac-out, for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Since fluid loss normally occurs in fault zones, fracture zones, or seams of coarse material, fluid migration does not always gravitate to the surface, thus making detection difficult. Once a fluid loss is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to mitigate fluid loss. If no surface migration is evident, resume operation while paying particular attention to fluid monitoring.

In the event of a fluid migration to the surface occurring, the Contractor shall halt all operations immediately, isolate the migration site, and recover fluids. Once the fracture is controlled, continue drilling operations with the operator paying particular attention to the fracture points

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.01 General

The product shall be jointed according to manufacturer's recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be exceeded.

Product shall be allowed to recover before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully reaming the bore to the required diameter, the product shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. When specified in the Contract Documents, a weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator,

The pull back and reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the excavation walls shall be filled with grout.

7. 05 Tunnelling Installation

7.05.01 General

The method of tunnelling shall be selected by the Contractor and shall be submitted to the Contract Administrator prior to commencement of the work for information purposes.

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall advance the ventilation system as a regular part of the normal excavation cycle.

The Contractor shall provide lighting in accordance with OHSA requirements for the entire length of the tunnel.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

In the event that excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the surface of the excavation shall be filled with cement grout. If an unexpanded liner is used, the space outside the liner plates shall be grouted at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property.

7.06 Instrumentation Monitoring

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement and ground stability.

Surface settlement markers for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at not greater than 5 m intervals along the tunnel alignment and as an array of three in ground (1.5 m depth) measurement points on the shoulder of the highway perpendicular to the alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within ± 1 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short term lane closures in accordance with the Ontario Traffic Manual (OTM).

In general, settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface. The assembly shall be placed in a drill hole and backfilled with uniform sand as shown on the Contract Drawings.

The Contractor shall install all surface settlement instruments a minimum of one week prior to the start of works.

The surface settlement instruments shall be clearly labelled for easy identification.

The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation recorded at the following time intervals:

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- Once per shift during tunnelling operations period; and

- Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrative for information purposes on a weekly basis. Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsection 4.02, the following represents trigger levels that define magnitude of movement and corresponding action:

- Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate of sequence of construction or ground stabilization measures to mitigate further ground displacement.

  If the Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

- Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.
  - No construction shall take place until all the following conditions are satisfied:
    - The cause of the settlement has been identified.
    - The Contractor submits a corrective/preventive plan.
    - Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
    - The CA deems it is safe to proceed.

The Contractor shall avoid damaging instrumentation during construction. Instrumentation that is damaged as a result of the Contractor's operation shall be repaired or replaced by the Contractor within one business day. The costs for replacement/repair shall be borne by the Contractor.

At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work.

9. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for providing all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement monitoring and instrumentations site restoration and for all other work necessary to complete the installation as specified.

Payment for the rigid or flexible pipe conduits installed inside the pipe liners shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor's operations (e.g. choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections shall be made on the following basis:

(a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.

(b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

Payment for removal of boulders/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and material charges.

Notes to Designer:

Under Section 7.01.06, minimum horizontal and vertical clearances to existing facilities shall be identified in the Contract Documents. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed. The number of exposures required to monitor work progress shall be specified in the Contract Documents.